NIMA Compression Standards

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NIMA Direction

- NIMA is going towards SCOTS
  - Standards based Commercial Of The Shelf
- The direction has been from Military Standards to profiles of commercial international standards
  - The first compression ARIDCPM was developed and defined by the Government
  - JPEG (the most successful compression) was a selection of the standard that was not commercial compliant
  - JPEG 2000 is fully commercial compliant
- Currently, NIMA has an effort to make profiles of the JPEG Military Standard
  - Support international use for NATO and other allies

Current Compression Standards

- MIL-STD-188-197A Adaptive Recursive Interpolated Differential Pulse Code Modulation (ARIDPCM) Compression Algorithm (NITFS 1.1)
  - Proprietary standard defined by Government
- MIL-STD-188-199 Vector Quantization Decompression
  - Used for Maps, Proprietary standard defined by Government
- MIL-STD-188-196 Bi-Level Image Compression
  - Group-3 and Group-4 Fax compression Standard
  - CCITT commercial standard rewritten as a military standard
- MIL-STD-188-198A Joint Photographic Experts Group (JPEG) image compression
  - ISO/IEC international standard (ISO 10918-1, ITU T.84)
  - Supported by N-0106-97 Bandwidth compression standards and guidelines document
- N-0106-97 Downsampled JPEG (tactical or NIMA Method 4)
  - Pre- and post-processing definition that uses 188-198A JPEG standard as the main compression engine

Future Compression Standards

- NIMA is developing a profile of the ISO/IEC compression standard 15444-1, JPEG 2000
- NIMA and other Government was involved in the development of JPEG 2000
  - Developed technology
  - Defined requirements
  - Support the compliance testing
  - Continue to support the documentation of the standards
- NIMA has supported other agencies in the development of this profile and standard
- Considering expanding the profile to support other parts of JPEG 2000 as needed by the customers of NITFS/BIIF/NSIF
  - Support JPEG 2000 Part 3 (Motion JPEG 2000)
  - Support JPEG 2000 Part 2 (MSI/HSI, TCQ?, other wavelets?)
  - Support JPEG 2000 Part 9 (JPIP, interactive streaming protocol)

JPEG 2000 Status

JPEG 2000 Compression Standards

- Part 1: specifies the minimum compliant decoder (e.g., a decoder that is expected to satisfy 80% of applications); International Standard (IS) was approved 12/00. This has been published by the ISO. www.jpeg.org
  - This is what NIMA will standardize for use in 90% of their applications. If you are compliant to this standard, you will be compliant to the future NSGI architecture. All NITFS 2.1 readers will be required to support the JPEG 2000 Part 1.
- Part 2: Describes optional features and value added extensions. International Standard (IS) was approved 01/01
  - We may wish to add extensions from Part 2, will add when required
  - Multiple component compression for HSI and MSI data
  - Trellis Coded Quantization may be of use for SAR imagery
  - Other wavelet filters and decompositions may be useful for SAR

JPEG 2000 Compression Standards

- Part 3: Motion JPEG 2000 with file format from MPEG 4. International Standard was approved 11/01
  - Does not take advantage of the inter-frame correlation
  - No limitation of image size or bitdepth as in MPEG 1,2, and 4
  - Motion Image Standards Board reviewing this technology, of interest to this group as well
- Part 4: Compliance testing procedures. Compliance test image and procedures are very important for the promotion of "compliant" standards and interoperability. International Standard was approved 05/02. Imagery is available on the internet.
  - Basis of what and how JITC will test NITFS 2.1 readers and writers for compliance.
- Part 5: Reference software: Two versions of reference software (JAVA, C++). International Standard was approved 11/01.

JPEG 2000 Compression Standards

- Part 6: Compound document. Being developed to support compound documents (text, graphics, and images) using the Mixed Raster Content (MRC) defined in ISO 16458. International Standard was approved 01/03.
  - Probably not interested at this time. We may want to reconsider if this becomes a commercial success.
- Part 7: withdrawn

New Work Items

- Part 8: Security: JPSEC
  - Addresses security issues, such as authentication, data integrity, protection of copyright and intellectual property, privacy, conditional access, to mention a few. Enables applications to generate, consume, and exchange secure JPEG 2000 bitstreams. At FCD stage 07/03.
- Part 9: (JPIP) Interactivity tools, APIs and Protocols
  - This part would support user interaction with JPEG 2000 images by providing APIs whereby applications could exploit JPEG features and protocols whereby this interaction can occur remotely over networks. At FCD stage 07/03.
- Part 10: 3-D and floating point data
  - This part will provide a mechanism for compression and decompression of volumetric data. At FCD stage 07/03.
- Part 11: Wireless
  - Focused on the transmission of JPEG 2000 data over wireless communications. includes techniques for protecting data from bit errors and error resilience. At FCD stage 11/03.

Profile Status

- NIMA Standards
  - Mr. Gordon Ferrari, NIMA/PST
- JPEG 2000 Profile
  - Current draft is version 1.8
    - Being sent to ISO/IEC SC 24 for acceptance in two weeks (Yes/No vote)
  - The profile of what NITFS 2.1 will support (NSGI profile)
- Developers guide
  - Working draft 1.1
  - Not much work done recently due to profile preparation. A new version should be completed this year
- NATO Air group 4 voted yes for support
- NITFS Technical Board voted yes

JPEG 2000 Profile

Overview of Profile Structure

- The goal of the profile is to define the JPEG 2000 codestream restrictions (limits of the compressed data) that all NITFS 2.1 compliant systems will be required to support.
  - While keeping in line with the commercial profiles to save money with SCOTS.
- The profile will also promote wide interoperability for all NITFS systems
  - National/primary dissemination
  - Tactical/Secondary dissemination
- Make recommendations that try to achieve the greatest functionality for the NSGI architecture
- Give examples of the most common processes that would occur using the JPEG 2000 compressed data.
- Define the interaction between NITFS file format and the JPEG 2000 bitstream headers

Overview of Profile Structure

- Profile: Define all the codestream limitations of JPEG 2000 Part 1.
  - This profile is the same as the ISO JPEG Profile 1 (right now)
  - We expect to add upon this when new hard requirements are defined
    - Will lead to additional future profiles
    - For example, we may add multiple component compression from Part 2
- NSIF/BIIF/NITFS Preferred JPEG 2000 Encoding (NPJE, BPJ2K01.00): Defines the recommended values of parameters to promote the most functionality and interoperability within the NSGI
  - Supports the multiple resolutions, quality levels, and tile parsing
- NSIF/BIIF/NITF with JPEG 2000: Describes JPEG 2000 within a BIIF wrapper
  - Addresses population of NITFS Image subheader fields: How do the values in the NITFS Image Subheader interact with the image header in the JPEG 2000 codestream

Overview of Profile Structure

- Annexes
  - Annex A: JPEG 2000 Process Flow: Defines generic flows for multiple processes that would performed by every NITFS JPEG 2000 system
    - Encoding process flow
    - Decoding process flow
    - Parsing data flow
      - Tile parsing, quality layer parsing, resolution parsing
    - Enhancement processes (not defined as of yet)
      - Future profiles may include wavelet domain enhancement procedures
    - Repackaging procedures
  - Annex B: JPEG 2000 Process Examples
  - Annex C: JPEG 2000 Commercial Profiles
    - Profiles 0 and 1 from the JPEG standard
  - Annex D: JPEG 2000 Suite of Standards

NPJE Profile

- NPJE Profile is compliant to ISO JPEG 2000 Profile 1
- The compliance class will be dependent on NITFS compliance class
  - We expect to support both JPEG 2000 Cclass 1 and 2
- The limitations of the JPEG 2000 Profile 1
  - Rsiz = 2 (Marker that states that this is profile 1)
  - The image size is limited to less than 2^{31}
  - Tiles are limited to no greater than 1024-by-1024 and must be square (XTsiz = YTsiz, XTsiz/min(XRsiz, YRsiz) $\leq$ 1024) or one tile for the entire image
    - For each tile, LL subband should be included that is no bigger than 128 on a side.

NPJE Profile

- The limitations of the JPEG 2000 Profile 1
  - The image and tile origins are required to be less than 2^{31}
  - There is a limit of 37 region of interests (ROI) for each image
  - Code-block sizes are limited to 2^6 (64 maximum to a side)
- Compliance classes are not specified in the profile and will be part of the compliance testing of the JITC
  - The commercial compliance classes are found in JPEG 2000 Part-4
  - The general concept is to guarantee decoding depending on the image size, memory and computational cost to the decoder

	Cclass 0	Cclass 1	Cclass 2
Image Size limits	128 x 128	2,048 x 2,048	16,384 x 16,384
Number of bands	1	4	256
Bit Depth	8	12	24

NSGI Recommendations

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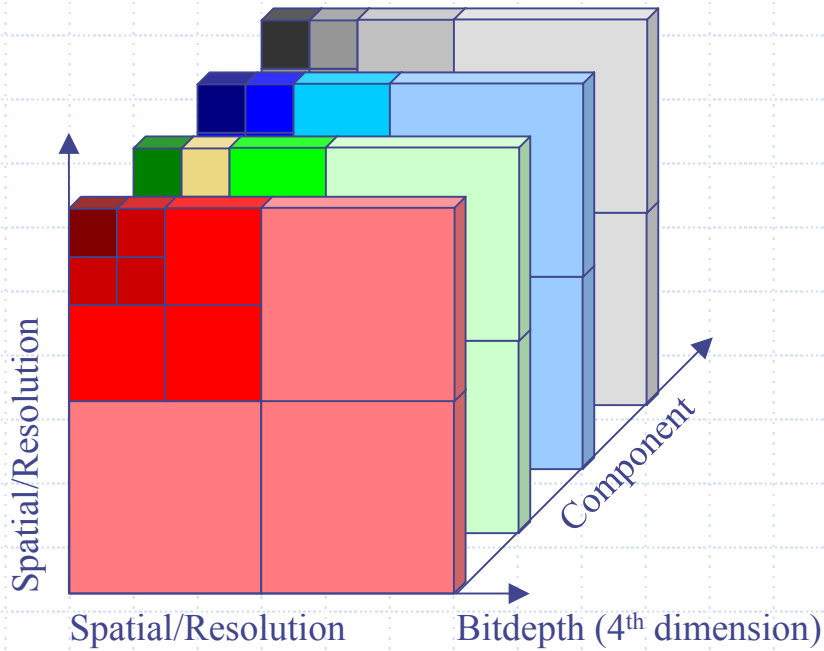
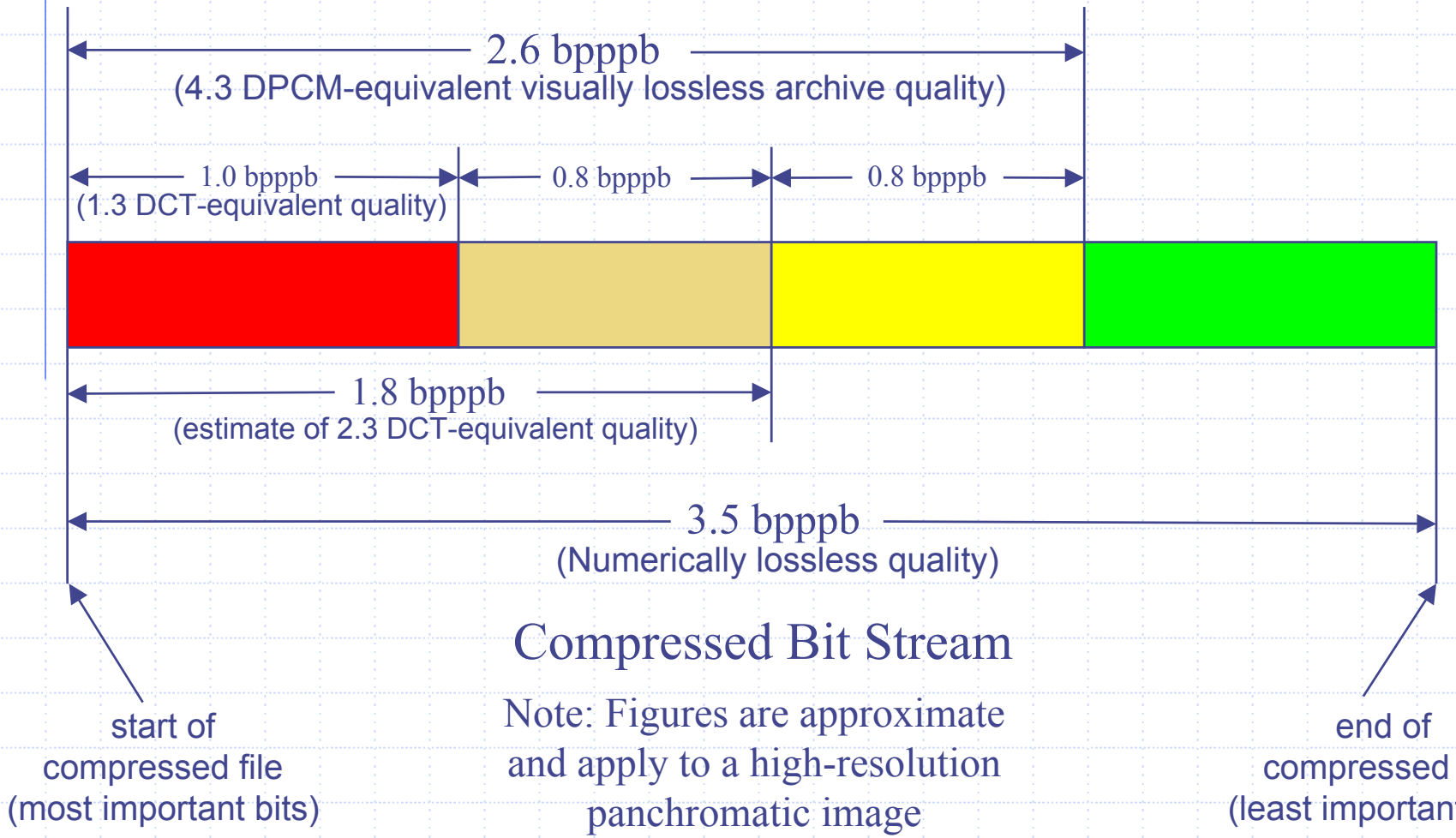
Progressions in JPEG 2000

- After wavelet processing, we have a four dimensional cube of data
  - Spatial/Resolution (two)
  - Component
  - Bitdepth
- JPEG 2000 allows progression along four dimensions
  - Layer (L)
  - Resolution (R)
  - Component (C)
  - Precinct or position (P)
- These are roughly equivalent as follows
  - Resolution & Precinct ⇔ Spatial/Resolution
  - Component ⇔ Component
  - Layer ⇔ Bitdepth



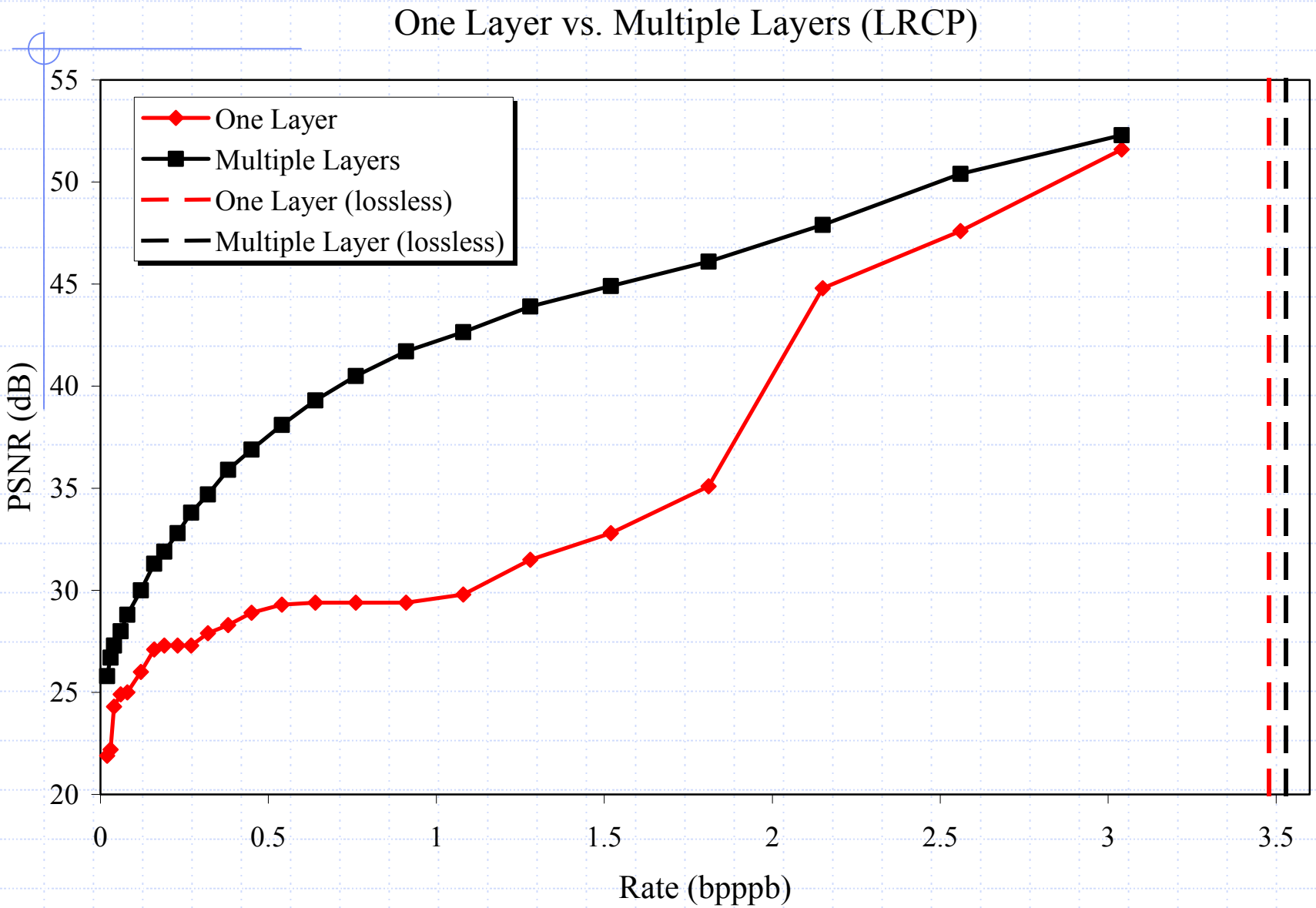
Wavelet processed components

Progressive Decoding Videos



Why Layers Are Important

Effects of Layering



Proposed Layers and Applications

- Layers enable *quality* scalability
- If *numerically* lossless compression is needed
  - Use the 5-3R integer reversible wavelet transform
  - 5-3R can also be used for lossy compression
- For lossy only compression
  - Use the 9-7I irreversible floating point wavelet transform
  - Better lossy performance than the 5-3R

Layer	Bits Per Pixel (bpp)	Application(s)
Layer 1 (5-3R filter)	Lossless	Radiometric
Layer 1 (9-7I filter)	Visual lossless	MC&G
Layer 2	3.5 bpp	MC&G
Layer 3	2.3 bpp	MC&G
Layer 4	2.0 bpp	MC&G
Layer 5	1.7 bpp	MC&G Visual exploitation
Layer 6	1.5 bpp	Visual exploitation
Layer 7	1.3 bpp	Visual exploitation
Layer 8	1.2 bpp	Visual exploitation
Layer 9	1.1 bpp	Visual exploitation
Layer 10	1.0 bpp	Visual exploitation and Tactical users
Layer 11	0.9 bpp	Tactical users
Layer 12	0.8 bpp	Tactical users
Layer 13	0.7 bpp	Tactical users
Layer 14	0.6 bpp	Tactical users
Layer 15	0.5 bpp	Tactical users
Layer 16	0.25 bpp	BW constrained users
Layer 17	0.125 bpp	BW constrained users
Layer 18	0.0625 bpp	BW constrained users
Layer 19	0.03125 bpp	BW constrained users

Choosing A Progression

RLCP Progression

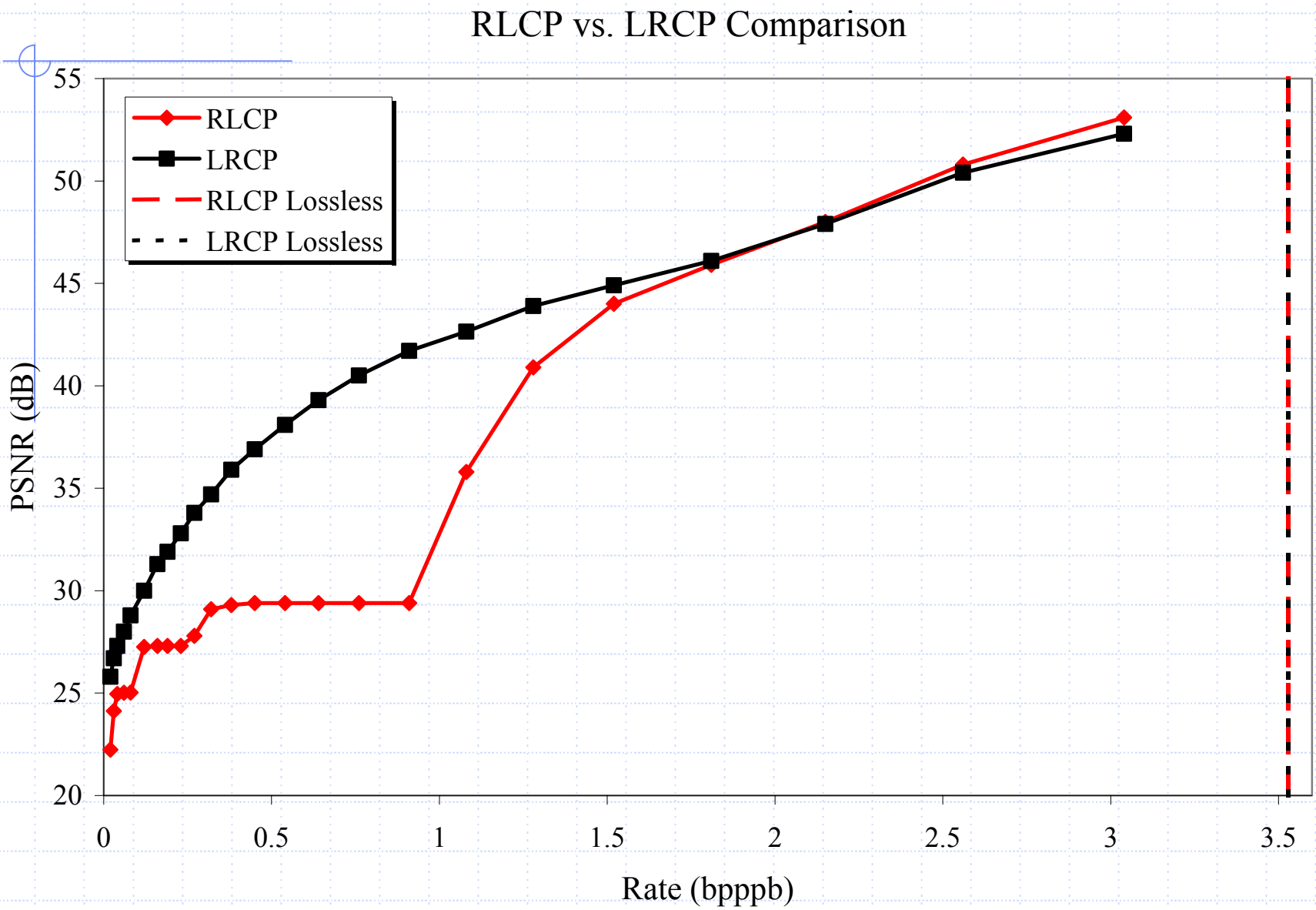
LRCP Progression

0.02 bpppb

0.02 bpppb

rlcp.avi

Effects of Progression



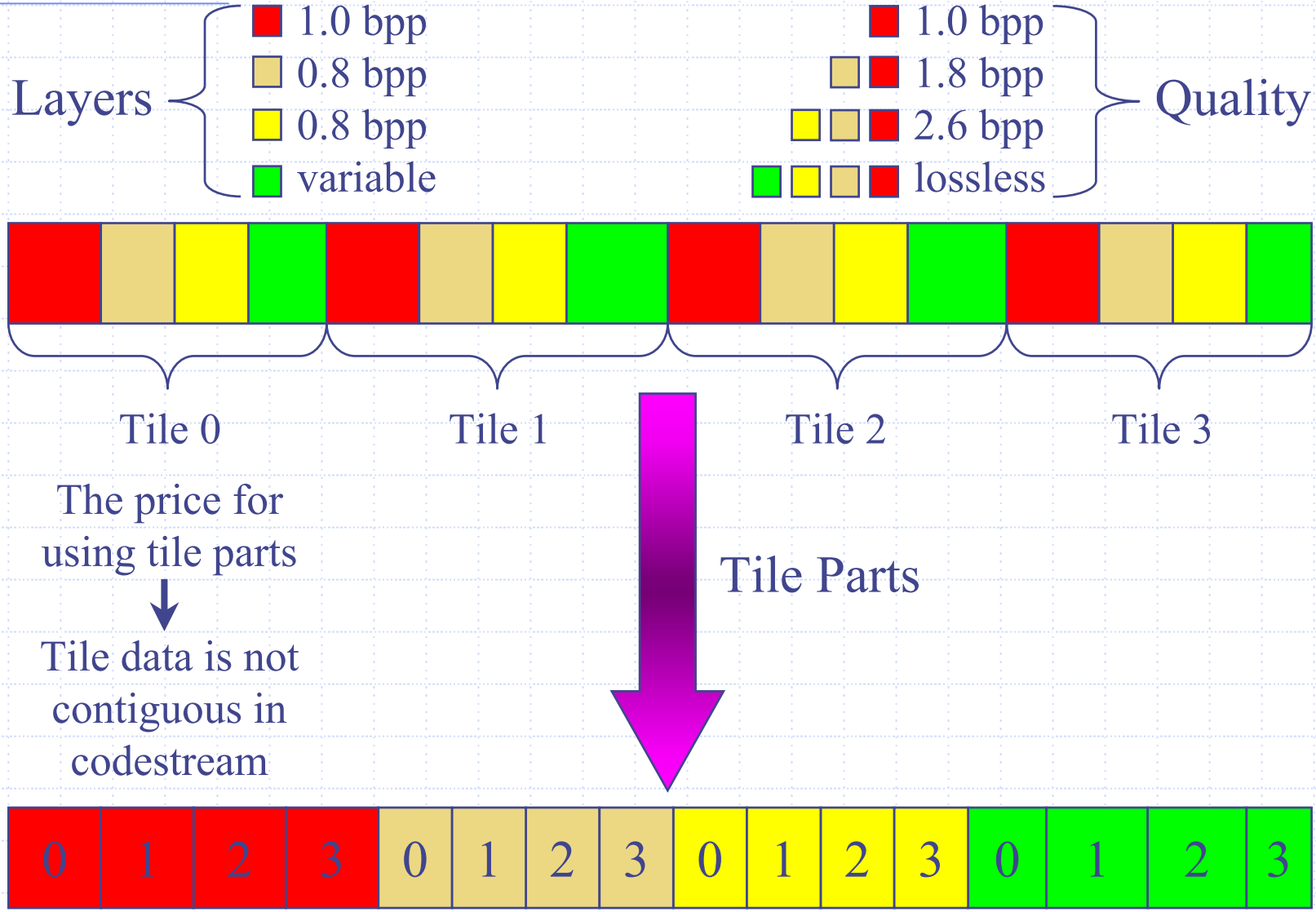
Progression Recommendation

- Recommend "LRCP"
  - Assume want best R0 quality as a function of rate
  - Other progressions will occur in commercial imagery!
    - Libraries must be able to read such files
    - Libraries should be able to change "transcode" from one progression to another
  - This has led to issues with IEC
- JPEG 2000 allows for the progression order to change within a file (POC marker)
  - Useful for interactive streaming sessions
    - Server streams data to user
    - User may tell server to concentrate on an area or resolution
  - If you don't want full resolution or have different resolutions within a mosaic

Tiles

- Tiles are independently coded sub images. Nothing crosses tile boundaries
  - Wavelet
  - Entropy coding
  - Layers
  - Progressions
- Tiles may be broken into tile parts.
  - Tile parts from different tiles can be interspersed in codestream
  - Only mechanism available to achieve "tile progression"
  - Impairs ability to randomly access a tile
- In general, need to parse data out of tiles to achieve a different image quality
  - If all tiles are compressed at 2.0 bpp and you want 1.0 bpp, then need to go into each tile and get the 1.0 bpp

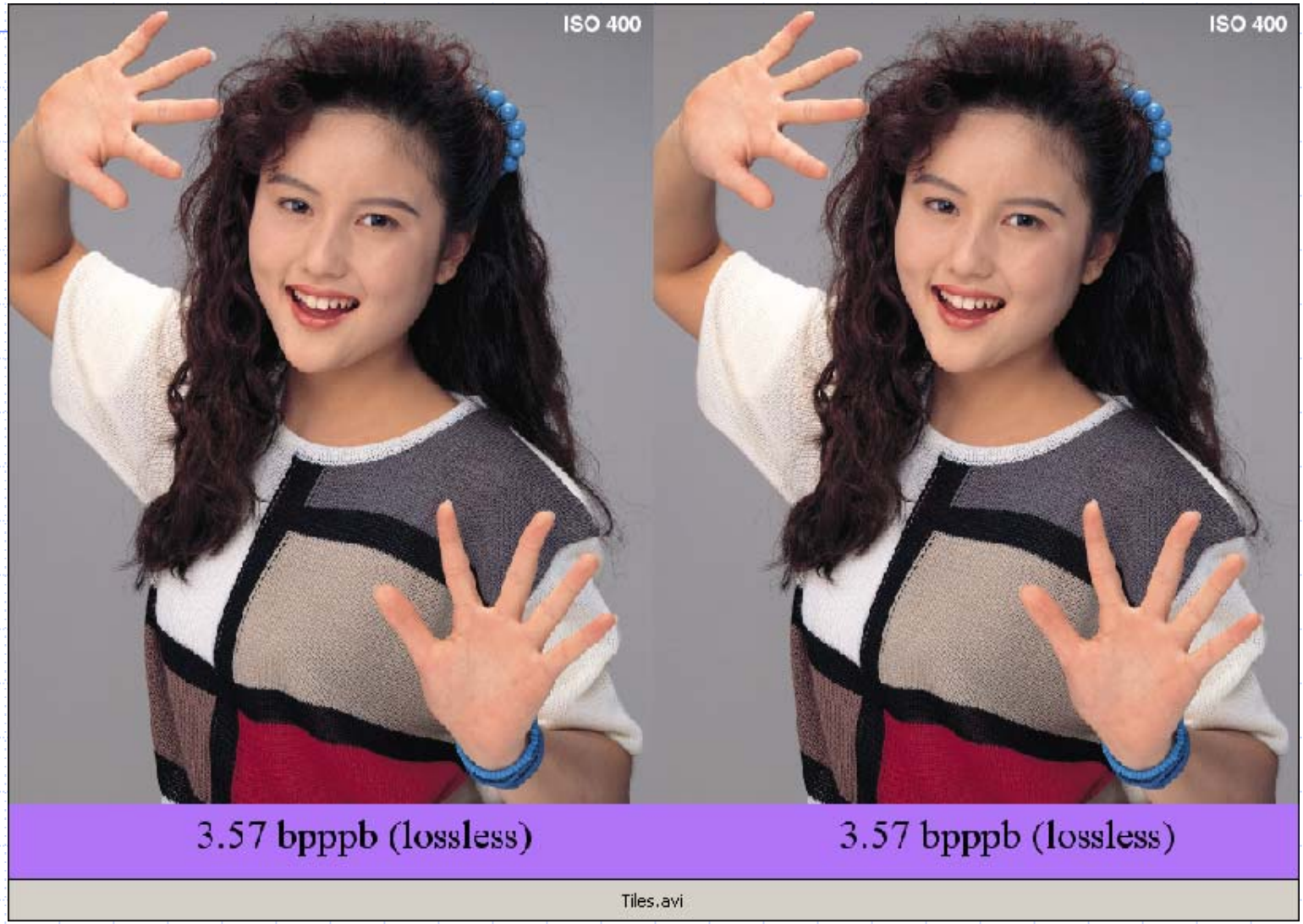
Tile Codestream



Need For Parsing

No Parsing Performed

Parsing Performed



Tile and Wavelet Recommendations

- Recommend images tiled at 1024 x 1024 pixels
  - Allow fast access to spatial chips
  - Five levels of wavelet decomposition (R0 through R5)
    - Enables resolution scalability
    - R5 is 32 x 32 in size
    - R6+ generation is an issue
      - Do more wavelet levels initially or mosaic R5s and wavelet transform
- Recommend one tile part per tile
  - Chipping is more important than "tile progression"
- Tile Length Markers (TLM markers) recommended to speed access
  - Appears in codestream main header
  - Can be used to derive pointers to start of each tile
- Packet Length Tile markers (PLT markers) recommended to facilitate parsing of packets
  - Appears in each tile header
  - Facilitates parsing of packets

Other Recommendations

- Code blocks
  - 64 x 64 in size recommended
    - Increase arithmetic coder efficiency
    - In commercial imagery may see 32 x 32 and possibly 1024 x 4
- Precincts (tiling within wavelet subbands)
  - Not recommending their use since we use tiles
    - Standard allows you to use both in one codestream
  - Will definitely see this in commercial images
- Reference Grid
  - Image offsets (XOsiz, YOsiz) set to (0, 0)
  - Tile offsets (XTOsiz, YTOsiz) set to (0, 0)
  - 1024 x 1024 tile size will allow us to chip and maintain these values
  - Imagery with other tile sizes or tile/image offsets may require manipulation of these values when chipped

JPEG 2000 Tag

Field	Name/description	Size bytes and format	Req. or Con.	Value Range
CETAG	Unique Extension Type Identifier Unique registered TRE identifier	6, BCS-A	R	J2KLRA
CEL	Length of User-Defined Data Length in bytes of data contained in subsequent TRE fields. (TRE length is 11 plus the value given in the CEL field)	5, BCS-N	R	Variable
ORIG	Original compressed data Indicates if the image is in the same original JPEG 2000 compression or it has been parsed to a new JPEG 2000 compression. The conditional fields (NLEVELS_I, NLAYERS_I, NBANDS_I) are only present if ORIG = 1.	1, BCS-N	R	0 - Orig. 1 - Parsed

JPEG 2000 Tag

Original compressed image information (the first JPEG 2000 Compression)				
NLEVELS_O	Number of Wavelet levels in original image Indicates the default number of wavelet decompositions levels performed in the original image.	2, BCS-N	R	00 - 32
NLAYERS_O	Number of Layers in original image Indicates the number of layers in original image.	5, BCS-N	R	00000 - 65535
NBANDS_O	Number of bands in original image Indicates the number of bands in original image.	5, BCS-N	R	00000 - 16384

JPEG 2000 Tag

	Layer information			
(This is the start of a repeating section for n = 0 to NLAYERS_O – 1.				
$LAYER\_ID_n$	Layer ID Number Indicates the number of layer being described. Layers are numbered from 0 to NLAYERS_O –1. 0 is the layer with the lowest bitrate.	5, BCS-N	R	00000 - 65535
$BITRATE_n$	Bitrate Indicates the bitrate target associated with the layer. This is defined in bits per pixel per band. It may happen that the bitrate was not achieved due to data characteristics. Note for JPEG 2000 numerically lossless quality, the bitrate for the final layer is an expected value based on past performance. If there is not a target bit rate, report the achieved bit rate.	9, BCS-A	R	Value 00.000000 – 37.000000

JPEG 2000 Tag

(This is the end of a repeating section.)				
	Conditional field if the data has been parsed			
NLEVELS_I	Number of Wavelet levels in this image Indicates the number of wavelet decompositions levels included in this image(s) as defined in COD.	5, BCS-N	C	00 – 32
NLAYERS_I	Number of Layers in this image Indicates the number of layers in this image as defined in COD.	5, BCS-N	C	00000 - 65535
NBANDS_I	Number of bands in this image Indicates the number of bands in this image as defined in SIZ.	5, BCS-N	C	00000 - 16384

NIMA JPEG 2000 Profile

- Current profile contains JPEG 2000 Part One
  - Fully commercial compliance
  - COTS software should be able to decode the profile encoded imagery
- Future profiles or additions to the profile
  - JPEG 2000 Part 2 for multiple component
    - Current profile can compress multi-band imagery band-by-band
    - Ability to compress multi-band imagery more efficiently (takes advantage of band-to-band correlation)
  - JPEG 2000 Part 3: Motion JPEG 2000
    - Scalable motion imagery compression
    - Less efficient compression than MPEG-2 or H.264 but more flexible for scalable transmission, image size, and other parameters
  - JPEG 2000 Part 9: JPIP Interactivity tools, APIs and Protocols
    - Allows for the interactive viewing of large images of limited bandwidth
    - More advanced GIAS (allows for partial imagery delivery)

NIMA JPEG 2000 Profile

- Future profiles or additions to the profile
  - Complex data compression
    - Optimization of Part 1 profile for complex data
    - Adoption of Part 2 technologies
      - TCQ
      - Different wavelets
      - Different subband decompositions
      - Component transform